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UNITED STATES DEPARTMENT OF AGRICULTURE

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U.S. FOREST SERVICE

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SUGGESTIONS FOR THE AESTHETIC TREATMENT OF LOW DAMS

By

M. B. Arthur, Hydraulic Engineer
2a Division of Engineering
5a Washington, D. C.

U. S. GOVERNMENT PRINTING OFFICE

8—7417

Suggestions for the Aesthetic Treatment of Low Dams

The elements to be considered in the design of dams are numerous, but they may be divided into four more or less distinct fields, which provide that dams shall be:

1. Hydraulically safe.
2. Structurally sound.
3. Aesthetically correct.
4. Economically designed.

To meet the first requirement, it is necessary for forecast the hydraulic conditions that the dam may be called upon to withstand, and then to provide for the safe handling of those conditions without undue damage to the structure or interruption to the normal functions of the project.

The question of structural soundness involves a correct analysis of the loads imposed on the structure, the design of suitable structural units to carry those loads without undue deterioration, and the selection of a site where the foundation will be adequate.

No attempt will be made herein to treat these problems which, being definite and concrete in character, are capable of being solved by engineering analysis expressed in feet, tons or dollars and thence converted to physical form by standard construction procedure.

The engineer is not usually credited with having the background of training ordinarily required for an appreciation of the abstract values which go to make up aesthetic perfection, but by an orderly and open-minded use of the devices and practices that are available through the efforts, advice, and cooperation of architects and landscape architects, there is no reason why a high degree of aesthetic perfection cannot be attained in engineering designs. It is a matter of fact that some of the so-called devices are nothing more than a simplification of present day practices which may in some cases effect lowered rather than increased costs, although more often the measures required will add to the expense of the project.

The requirement that a dam be economically designed covers a wide field. The type of dam selected should be that type which is best adapted to the site, and the arrangement of the spillway and other appurtenant structures should make the most of the site conditions. Consideration should be given to the availability of the

resources of native or local materials and labor, and of money with which to purchase such of these as are not readily available. But the designer should go beyond these things and study the structure in relation to the use which it serves to determine what justification there is for providing more than the bare minimum of structural and hydraulic adequacy. Since the majority of our dams are built to create lakes for recreational use, the main objective is in the stimulation of pleasure seekers in a setting of natural beauty and the dam, as the major unit in the development, should not strike a discordant note. This, then, is the reason and necessity for giving full attention to the matter of aesthetic perfection along with the more commonplace design features. Such perfection can usually be realized only through the cooperative efforts of architects, landscapers and engineers, and it is urged that such cooperation be made standard practice in the solution of these problems.

The following is a general analysis of the problem of dam aesthetics with some suggestions for treatment under different conditions which may be helpful. In most cases the objective is to make the dam less conspicuous, which may be accomplished by minimizing harshness and by conforming to a composition which tends to subordinate the dam to the natural setting.

The three elements which combine to set up the aesthetic value of dams are: (a) physical form, (b) kind of material used, and (c) surface treatment. Each of these will be discussed separately.

Physical Form. This is essentially an architectural problem of shape, proportions, and mass composition which is advisedly left to the architect for final determination. However, certain generalities can be stated.

Excessive use of straight lines and large areas of plane surfaces is frequently undesirable because of the contrast that they make with natural conditions. The crest lines of long dams that would normally be laid out in a single straight line can usually be changed to a long sweeping curve or a combination of curve and tangents at no extra cost and sometimes at a saving in height through better fitting of the dam to the foundation.

In the use of head walls training walls, and spillway channel walls, it is of hydraulic as well as aesthetic advantage to use smooth curves instead of angular direction changes. Exposed faces of walls should have a slight batter back from the vertical,to avoid the illusion of tipping forward created by plumb surfaces. A battered face also creates an impression of stability and resistance to thrust which is often very desirable in engineering structures.

It is frequently of advantage to follow the practice of making the entire structure conform in appearance to the theory of functional lines; that is, to so shape the units of a structure that their outline conforms to the structural functions which they fulfill. The preliminary and final design of the Granite Basin Dam, Region 3, illustrates this point, as shown in Figure 1.

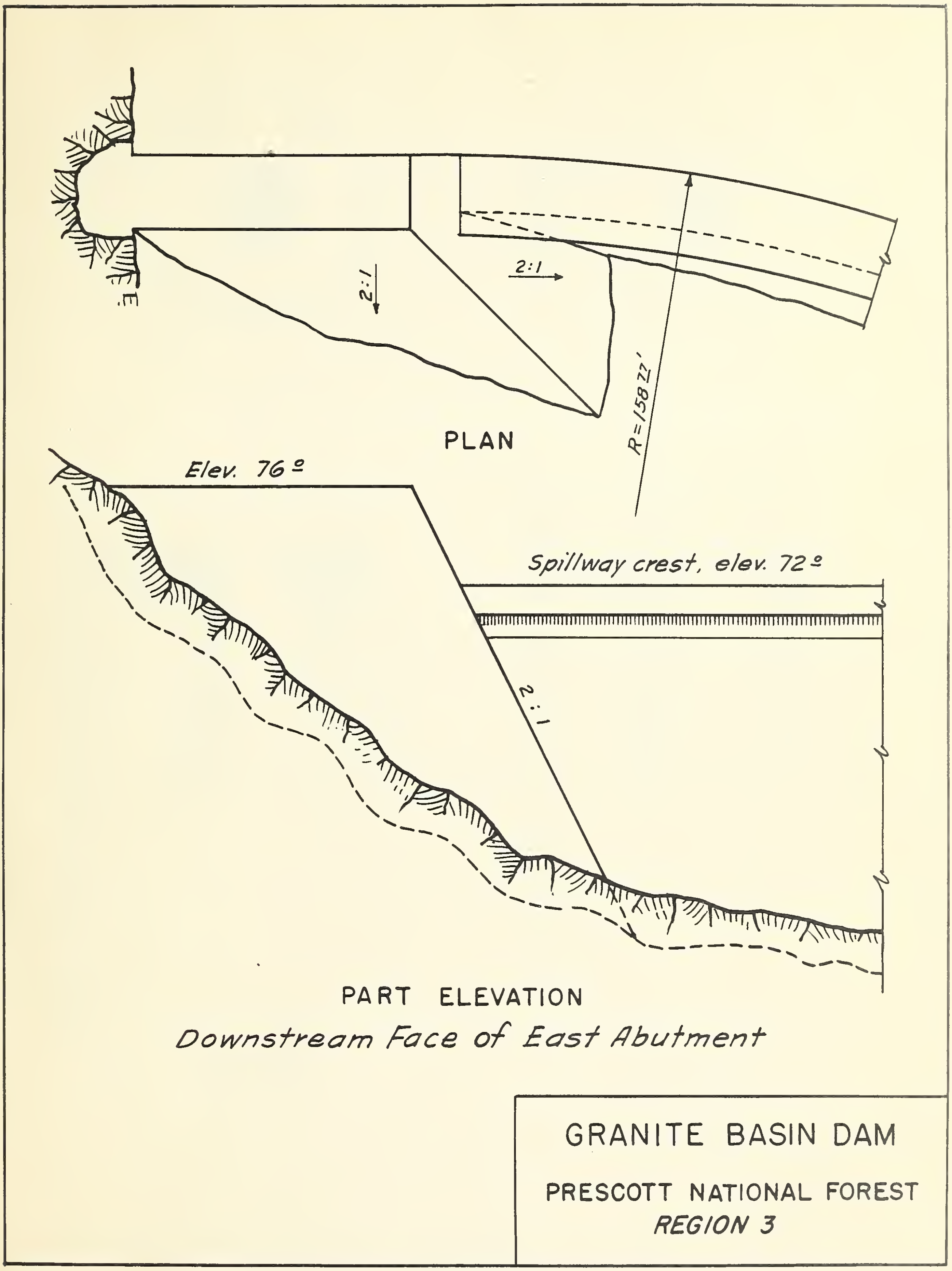
The dam is a thin concrete arch with short gravity abutment sections at each end. The initial design made use of the conventional vertical radial plane in making the transition from the arch to the abutment. The functional design made visual use of the value of the abutment as a thrust block by widening its base and giving it the appearance of greater mass and stability. The new transition plane is radial, and has the same slope as the downstream face of the abutment. The increased concrete yardage was negligible.

The spillway and gate operating platform of the Cedar Creek Dam, Region 8, is another illustration of the architectural treatment of a conventional engineering design. In this project the outlet gate was combined with a vertical shaft spillway, requiring an operating deck mounted on piers over the spillway shaft. The initial and final designs are shown in Figure 2. Note the greater consistency of treatment of the final structure in contrast with the abruptness of the piers in relation to the projecting edges of the platform in the original design.

Kind of Material. While kind of material used in the construction of dams may sometimes be selected largely for the aesthetic value of the material itself, more often it is a matter of selecting economically available materials which are best adapted to the engineering peculiarities of the damsite. There are various ways of treating and arranging whatever materials are selected, to bring about a considerable degree of aesthetic accomplishment.

We are most frequently concerned with soil, stone masonry, or concrete, sometimes individually, but more often in combination with each other. Each of these lends itself to more or less simple methods of aesthetic treatment which at least approach the desired goal.

Earth embankments are very common elements of small recreation lake developments and fortunately, they usually can be graded and vegetated so that they become unobtrusive features in the general landscape. The introduction of native and self-sustaining vegetation on the downstream slope and on the banks adjacent to the abutments which have been disturbed during construction is particularly desirable. This treatment serves the dual purpose of dressing up the dam and protecting the slopes from erosion. The vegetation should be limited to grass or low-lying creeping vines. Trees or tall shrubs with long root systems are never permissible because their roots, having a strong tendency to seek water, are drawn toward the upstream face of the dam and may become a serious menace to leakage through the embankment.


2:1
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PLAN
Elev. 76º
Spillway crest, elev. 72º
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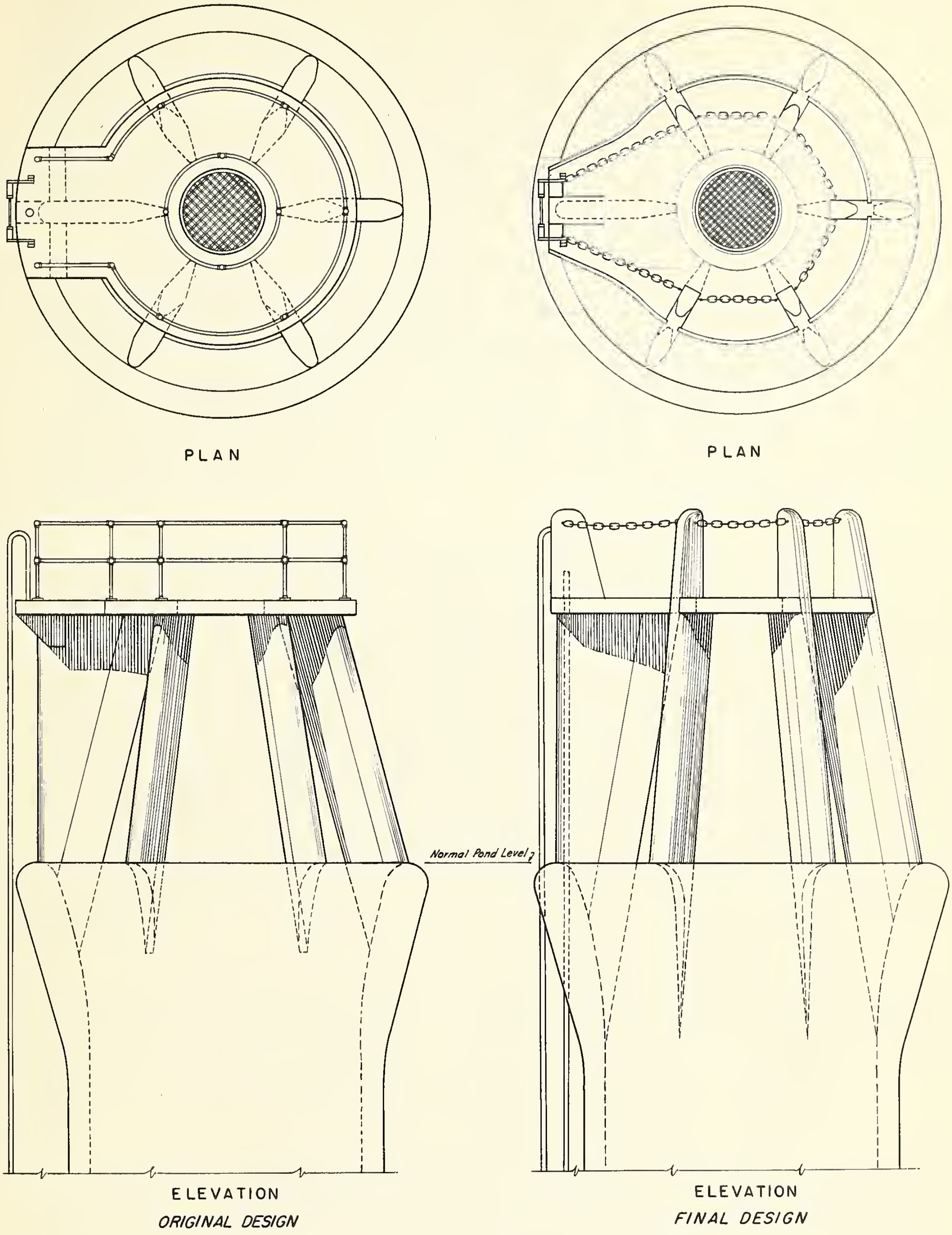
PART ELEVATION
Downstream Face of East Abutment
GRANITE BASIN DAM
PRESCOTT NATIONAL FOREST
REGION 3

FIGURE 1.



REINFORCED CONCRETE SPILLWAY SHAFT AND GATE STRUCTURE FOR

CEDAR CREEK DAM

OUACHITA NATIONAL FOREST
REGION 8

FIGURE 2.

In cases where the normal slope of the dam on the downstream side intersects the abutment slopes to form an abrupt change in direction of the contours, it will often be of help to relieve the severity of the intersection by placing additional fill in the corner to round out the contours. If well done, this procedure will frequently obviate the necessity for providing paved gutters to carry the surface run-off that might be expected to collect in the more sharply formed intersections. It is often equally desirable to place a fillet on the upstream side of the dam down as far as the low water line.

The cost of making this corner fillet will be approximately proportional to the yardage used. It takes 20 cu. yds. of fill per vertical foot to round out a right-angled intersection to a 50 ft. radius; a 75 ft. radius requires 45 cu. yds.; and a 100 ft. radius requires 80 cu. yds. per foot of height. Using a 75 ft. radius contour curve at both ends of an embankment which is 25 ft. high would require 2250 cu. yds. of fill. If the cost of placing the fill is 40 cents per cu.yd. the cost of the fillet would be $900.

Treatment of the surface of the upstream face of earth dams must be determined first by the requirement for wave protection, influenced by the availability and appearance of material. Ordinarily a loose layer of large field stone or quarried rock answers all requirements satisfactorily. It is effective in breaking up surface waves, it quickly weathers to become relatively inconspicuous, and, being of native rock, does not appear unnatural. There may be situations where the rock that is available is of flat slabby nature, in which case it may be necessary to place the riprap by hand, laying the flat stones on edge, normal to the face of the slope. The upper surface of this type of paving should be left somewhat rough and irregular, as it is more effective for breaking up wave action, and is also more satisfactory aesthetically.

For structures used in combination with earth dams, and sometimes for the entire dam, some sort of masonry construction is almost always required. The alternatives from which to select are: 1, stone masonry; 2, concrete; and 3, a combination of stone masonry veneer over a concrete structural unit.

Stone masonry is almost invariably the first choice of the architect or landscape architect if there is suitable stone available and if competent supervision can be obtained to build it satisfactorily. The advantages are entirely aesthetic, because rubble masonry made of local stone blends most favorably with the usual forest background and, as a rule, renders its structures far less conspicuous than its alternative, concrete.

Under average conditions, the unit cost of rubble masonry construction is 25 to 35 percent higher than concrete, and in most cases, stone masonry is neither as sound structurally nor as free

from leakage as is concrete. From the viewpoint of hydraulic design, masonry is more costly to use because its rough surface requires the use of higher coefficients of roughness, which result in lower coefficients of capacity as compared with concrete structures of the same size. This feature is emphasized because stone masonry in which the mortar is finished off flush with the outer rock surfaces is usually not acceptable to the landscape architect, who prefers a well raked and recessed joint so that the stone surface is the predominating element.

For example, assume an open channel 10 feet wide and 5 feet deep with a slope of one foot per hundred (0.01). A channel of this size, when lined with concrete, will maintain a steady flow of 975 cu.ft. per second. A rubble masonry lined channel of the same size and slope would have a capacity of only 455 cu.ft. per second, or only 47 percent of the concrete channel capacity. Looking at the problem in another way, how large would the masonry lined channel have to be in order to carry 975 cu.ft. per second on a slope of 0.01? The answer is 13.2 ft.wide and 6.6 ft.deep, or 1.75 times as large. (n, the coefficient of roughness = 0.014 for concrete and 0.030 for rubble masonry with well-raked joints). For flush jointed masonry surfaces (n = 0.020), the answer is 11.6 ft. wide and 5.8 ft. deep, or 1.35 times as large.

It is evident that hydraulic structures made of stone masonry will as a rule have to be appreciably larger than would concrete structures of the same hydraulic capacity, and as the unit cost is also greater for stone, the total cost of the structure will often be 40 to 50 percent greater if stone masonry is used. There will be special locations where the cost of sand and cement is exceptionally high, or where there is an abundance of stone suitable in size, shape and quality, in which cases the cost comparison is more favorable to stone masonry, but there will be others where suitable stone cannot be obtained. Each project should be analyzed by itself, and masonry used if its cost can be justified.

The foregoing comparison is based on mass concrete. In situations where sand and cement costs are high, the economic advantages in the use of thin concrete sections with steel reinforcing are apparent, which makes the stone masonry structure appear in an even less favorable light from the standpoint of cost. In such cases, the use of a stone masonry veneer should be considered. It should be recognized, however, that in climates which offer much freezing weather, the use of veneers may result in rather expensive repair and maintenance charges during the life of the structure and in the possibility of future unsightly cracks which are hard to eliminate. The use of a relatively thick stone veneer with frequent and substantial ties to the concrete is most essential if veneer is to be used where the weather exposure is severe.

Where stone masonry is used, it must be given appropriate attention for engineering and aesthetic sufficiency. Such factors as quality of the stone, direction of major bedding and jointing, thoroughness of bedding and use of mortar, striking of the joint surfaces, choice of sizes and colors of face stones, and other technical details should be completely outlined in the detailed specifications for each project. For suggestions in regard to this phase, see "Random Rubble Masonry, Its Structural Use and Design" by W. Ellis Groben, Consulting Architect, which was distributed from the Washington Office of Engineering in April, 1937. Attention is also invited to "Stonework for Walls" by A. D. Taylor in the January, 1939 issue of Pencil Points magazine.

Even though stone masonry is most desirable from an aesthetic point of view, it is evident that it is not always practicable, and it is therefore important that a thorough study and test be made of the possibilities of the use of concrete which has been given special treatment as to surface texture or color to make it conform more closely to aesthetic requirements.

It has already been stated that the most important objection to the use of concrete is that its characteristic smooth, light colored surfaces are highly reflective of light, and are generally very conspicuous in contrast with the naturally subdued tones of forest backgrounds. Ironically enough, it has been the common habit to accentuate this trouble by the practice of rubbing the surfaces of finished concrete structures with carborundum stones, which usually results in even lighter colored surfaces having a far greater coefficient of reflection. It is admitted that with the passage of time, natural weathering tones down these factors to some extent, but it does not seem necessary to start off with such a severe handicap.

The reader's attention is directed to "The Aesthetic Treatment of Exposed Concrete Surfaces," by W. Ellis Groben, Consulting Architect, which will be available for distribution at an early date.

In suggesting a remedy for this situation, we are somewhat handicapped by lack of knowledge of what the long range results may be of measures which seem to be of definite value during the early life of the structure. This refers particularly to the use of integral and surface applications of coloring matter. Consequently, any major steps taken should be considered carefully, and opportunity should be given for all parties interested to review the proposal before any such construction is started.

Before taking up the problem of adding color pigment to concrete, it may be worth while to consider what determines the color of untreated or natural concrete. The major influence on the color of the finished concrete is the cement. The fine aggregate has a minor influence, and the coarse aggregate has very little unless the surface is brushed while the concrete is still green or altered

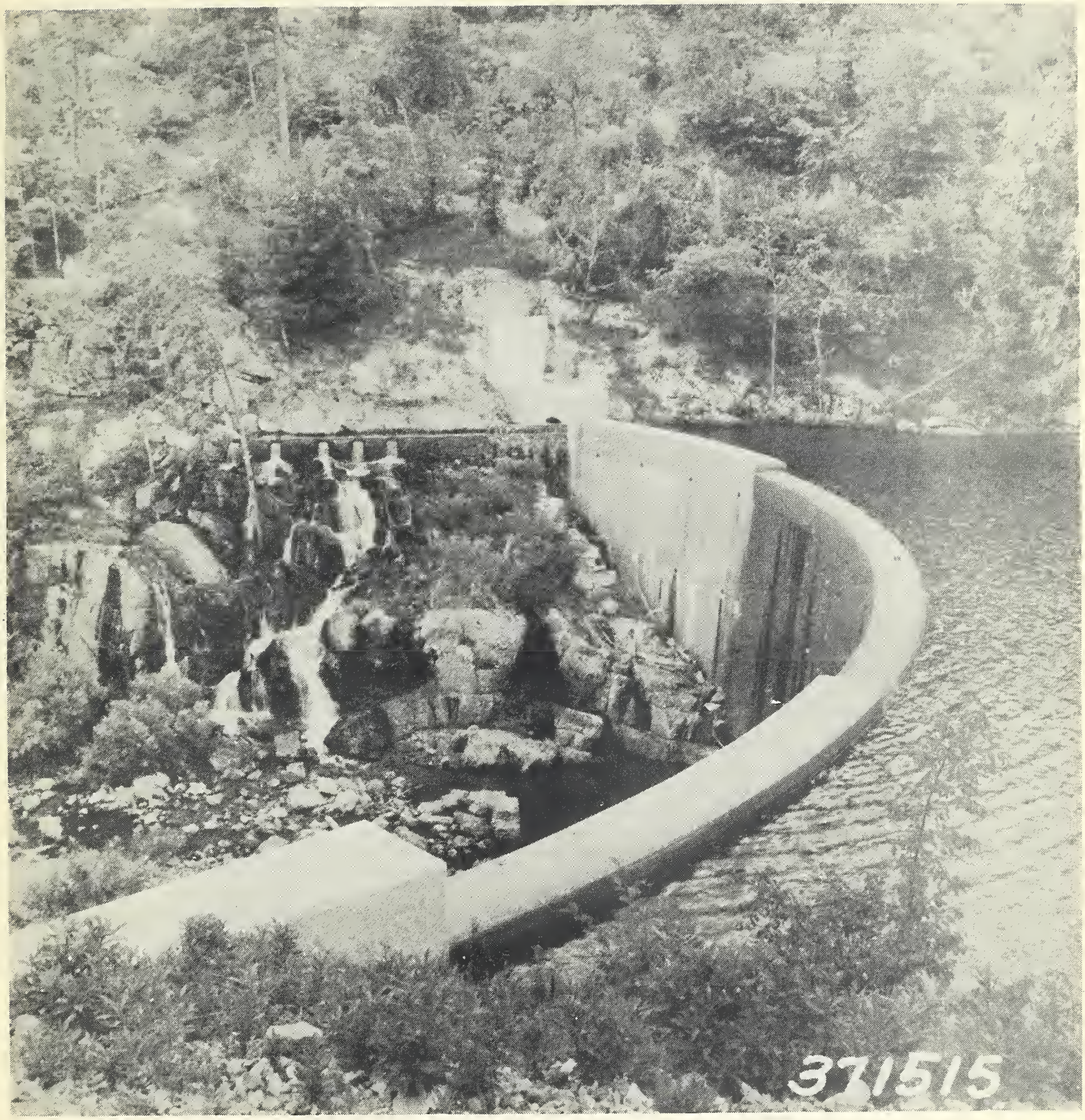
by a hammer treatment after hardening. Different brands of cements from different limerock areas show a rather wide variation of color, but the usual result is a rather light gray concrete surface.

Natural weathering processes almost always tend to darken and subdue the initial color, but ordinarily it takes several years to produce a moderately subdued tone that would be aesthetically acceptable for the uses considered herein. Sometimes local conditions are such that discoloration from weathering will be accelerated by an habitually smoky atmosphere, or, in the case of dams, by natural or artificial stream polution. A case of this latter type was recently observed at the Saline Dam on the Ouachita National Forest, Region 8. At certain seasons of the year there is a considerable concentration of tannic acid in the water, probably due to the predominance of oak trees on the watershed. The acid-bearing water, in passing over the spillway of the concrete arch dam, changed the color of the concrete to a very dark brownish gray in a single year's time. Unfortunately, there are large non-overflow abutments at each end of the dam which continue to show the original light gray color. Figure 3 is a photograph of the dam, which forms Shady Lake.

In order to have the benefit of subdued and inconspicuous coloring from the very beginning, when most dams are subject to the most critical observation, it is suggested that the use of coloring admixtures be attempted. The objective will usually be to make the concrete structures as inconspicuous as possible, consequently the color used should be the one which will harmonize best with the general environment, there being no one color or shade that will serve for all locations.

In the Ohio Valley or the Piedmont plains, for example, where there are few exposed rock surfaces and the soils are predominantly brown or red, a weathered brown is probably the color to be used. On the other hand, in the High Sierras or the Rocky Mountains there are wide areas of cold gray granites and gneises exposed to view, in which environment a subdued gray color would seem to be required. It is believed that coloring for dam concrete should be limited to variations of these two colors, that is, brown or gray.

It is not intended that this article shall be the excuse for embarking on a widespread and uncontrolled program of the use of colored concrete. It should be recognized as a possible solution of certain aesthetic problems stated herein, and as such, should be used cautiously and judiciously until such time as its value has been established or disproved. The approximate cost involved in the use of color admixtures will average around 50¢ to $1 per cubic yard of concrete, varying with the color intensity.



Saline Dam at Shady Lake
Ouachita National Forest, Region 8
FIGURE 3

This is so low, there will be little justification for omitting coloring if the results measure up to expectations.

The same method of approach should be used in regard to suggested methods of surface application of color to old concrete surfaces. It is possible that some of the more offensive completed projects can be greatly improved by this method, but materials, methods of application, and costs are not sufficiently well established to be reported or recommended at this time.

M. B. Arthur,
Hydraulic Engineer.

Revised 4-25-39